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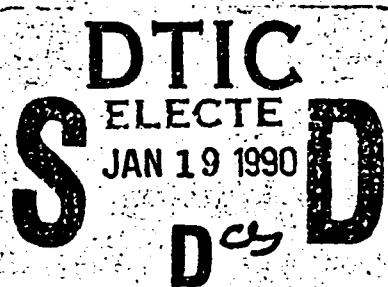
40 Years
1948-1988

RAND

Global Annual Snow Accumulation by Months

Charles Schutz, L. D. Bregman

February 1988



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Charles Schutz, L. D. Bregman

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40 Years
1948-1988

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PREFACE

The data presented in this Note represent an attempt to gather in one place and one format all available analyses and observations of annual snow accumulation by months from around the globe up to 1976. Methodologies were developed to show the global snow-depth data as a set of compatible mean-monthly snow accumulations, as of the last day of each month. The resulting climatological summary has been used for a comparison with snow-depth computations from a general circulation model (GCM). The data have also been useful for initializing GCM calculations.

The snow-accumulation climatology was originally developed as part of the RAND/National Science Foundation/Defense Advanced Research Projects Agency Climate Program, one of whose aims was the systematic comparison of model simulations with observed climate. Data more recent than 1976 have not been collected, since the Climate Program has not been continued at RAND. Other RAND publications related to the subject are the seasonal *Global Climatic Data for Surface, 800 mb, 40° mt* by C. Schutz and W. L. Gates, which appears in R-915-ARPA, R-915/1-ARPA, and R-915/2-ARPA for January, R-1317-ARPA for April, R-1029-ARPA and R-1029/1-ARPA for July, and R-1425-ARPA for October. These climatologies are available from the RAND Publications Department, and the tabulations in this Note are available on tape from the Data Facility within RAND's Computer Information Systems Department.

RAND Corporation funds were used to prepare and publish this Note.

SUMMARY

The compilation of observed mean monthly snow accumulations for the globe was taken from a variety of climatological sources and formats. They were reformatted to fit the global 4° latitude by 5° longitude grid of the RAND coupled two-level oceanic and two-level atmospheric general circulation model (GCM). The results are presented in the form of machine-analyzed isopleths on global maps, global grid-point tabulations, and global means. These products were used at RAND to initialize GCM calculations, to facilitate comparisons with global integrations from the GCM, and as a global climatological summary.

The snow-accumulation data given here were derived from observed data from various sources, presented in a variety of formats. Most of the monthly measurements were from scheduled snow-depth observations made in the Northern Hemisphere that were published before 1976. These data were gathered and developed into monthly climatologies, expressing conditions representative of the last day of each month, by the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL). To supplement the CRREL summaries, a pseudoclimatology of monthly snow accumulations was developed at RAND for the 4° latitude by 5° longitude grid points through the data-sparse areas of China, Greenland, the Arctic basin, and the Antarctic. Our methodology included an empirical evaluation of many regularly observed weather variables, including precipitation and temperature, taking into account cyclone tracks, weather source regions, and other items. Air mass modification as related to latitude and terrain was also considered.

Monthly ice-pack limits from the U.S. Navy Oceanographic Office were used to extend the "zero" snow-accumulation line over the oceans. Unfortunately, through Africa and South America, where the only accumulation is on the highest mountains, RAND's 4° by 5° grid was too coarse to pick up the variations. However, not more than two grid points were involved. The net result is what we consider to be the best mean-monthly snow-depth climatology currently available for the globe.

ACKNOWLEDGMENTS

Sincere appreciation is extended to analysts at the Cold Regions Research and Engineering Laboratory (CRREL), Corps of Engineers, U.S. Army, for sharing their many atlases and reports on snow research. We would also like to thank Professor N. Untersteiner of the University of Washington for his helpful suggestions and review of the evaluation of Arctic snow conditions and Professor Arnold Court of California State University, Northridge, for his significant contributions. Thanks are also extended to several RAND colleagues: to E. S. Batten and M. E. Schlesinger, who originally suggested the investigation, and to W. L. Gates, H. B. Henning, and R. R. Rapp, who reviewed the manuscript at various times and extended many valuable suggestions.

At the time of his death, Charles Schutz left a nearly complete manuscript of this Note. His manuscript was edited and put into final form for publication by F. W. Murray.

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I. INTRODUCTION

The climatological data presented in this Note describe the global distribution of mean-monthly snow accumulations shown in the form of tabulations for the grid used by the RAND general circulation model (GCM)[1]. The nodes of the grid are at intervals of 4° latitude from 2°N to the poles and of 5° longitude from the prime meridian east and west. The singularities at the North and South Poles are each represented as 72 separate grid points with common values. Figures A.1 and A.2 in the appendix show the locations of the grid points as plotted on polar stereographic maps.

The original data came from a variety of sources and formats. Most of the reported monthly measurements were from scheduled snow-depth observations in the Northern Hemisphere. For the most part, the measured snow depth at a given time is the same as the net accumulation from the beginning of the snow season up to that time. Over permanent ice caps, as in Greenland and Antarctica, there must be some modification of this concept, for the snow depth may technically be considered to be hundreds or thousands of meters, with an accumulation period measured in millenia. Thus in this study it is proper to speak of monthly *accumulation* as the total amount of snow that fell during the month less any loss to evaporation and melting. Where there is no ambiguity, *depth* can be substituted for *accumulation*.

Monthly accumulations from the data-sparse areas of Greenland, the Arctic basin, the Antarctic, and China were carefully contrived from a combination of whatever observed weather variables were available, including precipitation and temperature, weather sources, air masses, and so forth. Storm track and terrain considerations were used to limit interpolation between isolated data points. Great care was also taken to consider other sources of accumulation, such as deposition (hoarfrost), drifting snow, and the accumulation of ice crystals. In these cases, stratigraphic (core-type) measurements proved a useful source of information. Therefore, the resulting grid-point data are a

one-of-a-kind climatology based on snow depth and associated weather observations, global weather patterns, and a great deal of synoptic experience.

Data selection and processing and the methodologies used for developing global mean-monthly snow-depth values for data-sparse areas are discussed in Sec. II. The appendix contains tabulations of mean-monthly snow accumulation at each node of the 4° by 5° global grid for each of the 12 months. The number 0 in the tabulations denotes either zero accumulation or missing data, whereas the number 1 represents a trace. All data represent conditions on the last day of the month.

II. DATA SELECTION AND PROCESSING

This section briefly describes the data sources and methodologies used in processing the snow-related data. After a careful review of all known data sources, we feel confident that the material presented here represents the best snow-depth climatology available through 1975. These tested data can be used for initializing a GCM, for comparison with a model's global simulations, or separately as a climatological summary. A cursory review of the content, processing, and limitations of each data set follows. However, the most complete information covering our selected data will be found in the referenced publications.

Snow accumulation may not always result entirely from precipitation, since blowing snow, ice crystals, rime ice, hoarfrost, and the like also contribute to the total. However, most accumulations from these sources are small and difficult to evaluate, so, unless otherwise noted, only snow accumulated from precipitation is represented here.

NORTHERN HEMISPHERE

Except for Greenland, the Arctic basin, and China, Northern Hemisphere data were taken largely from observations of mean-monthly snow depths compiled by analysts at the U.S. Army's Cold Regions Research and Engineering Laboratory (CRREL) [2]. These Army records cover a period of approximately 20 years; however, CRREL did not prepare maps for the data-sparse months of June, July, August, and September. For the present study, breaks in the isopleths on the Army maps that were available were filled in by consulting temperature and snow data from supplementary sources, including an Atlas of Chinese Climatology [3], Soviet data from Borisov [4] and Rikhter [5], Dickson and Posey [6], and U.S. data from the Department of Commerce [7]. The Army data were further expanded during the coldest months with mean monthly ice limits from the U.S. Navy Hydrographic Office [8].

An attempt was made to develop snow accumulation values over water areas that are completely or mainly covered with pack ice. For this purpose, the "zero" snow accumulation lines were taken to be the boundaries of areas of greater than 5/10 sea ice cover as shown in Ref. 8. All grid points that fell within these lines in a particular month were given snow-accumulation values. For example, the Sea of Okhotsk and the South Bering Sea between the USSR and Alaska are usually covered by ice during January, February, March, and April. Snow accumulations assigned to the grid points during these four months reflect values at surrounding land points. All of the "supplemental" grid-point data for each month were stretched empirically. Special attention was given to the precipitation patterns, temperature, cyclone paths, air mass modification, latitude, and terrain.

GREENLAND

Greenland is a massive island, ice-covered and uninhabited beyond its coasts, extending from about 60°N to 82°N and from 12°W to 72°W , as shown in Fig. 1, after Bader [9]. Thirty-four grid points on the RAND 4° latitude by 5° longitude grid are fully representative of the ice cap. A number of other points represent varying proportions of land and the surrounding waters. All 13 weather reporting stations are along Greenland's coasts, as shown in Fig. 1 and listed in Table 1. This station distribution complicated our computations of snow accumulations, since the ice cap rises to about 3000 m in a broad plateau centered near 72°N , 40°W (dashed contours in Fig. 1).

Weather systems that regularly invade Greenland are dramatically modified by the orographic effect of the ice cap, and precipitation amounts vary greatly from the coast inland. The solid isopleths in Fig. 1 further indicate that the annual water equivalent precipitation (expressed in mm) is greatest south of 72°N and in the west. Therefore, Greenland's data-sparse interior proved to be a complicated and difficult area for which to develop a realistic snow-accumulation climatology. Since virtually the entire island is covered with a deep permanent layer of snow and ice, the present study is concerned only

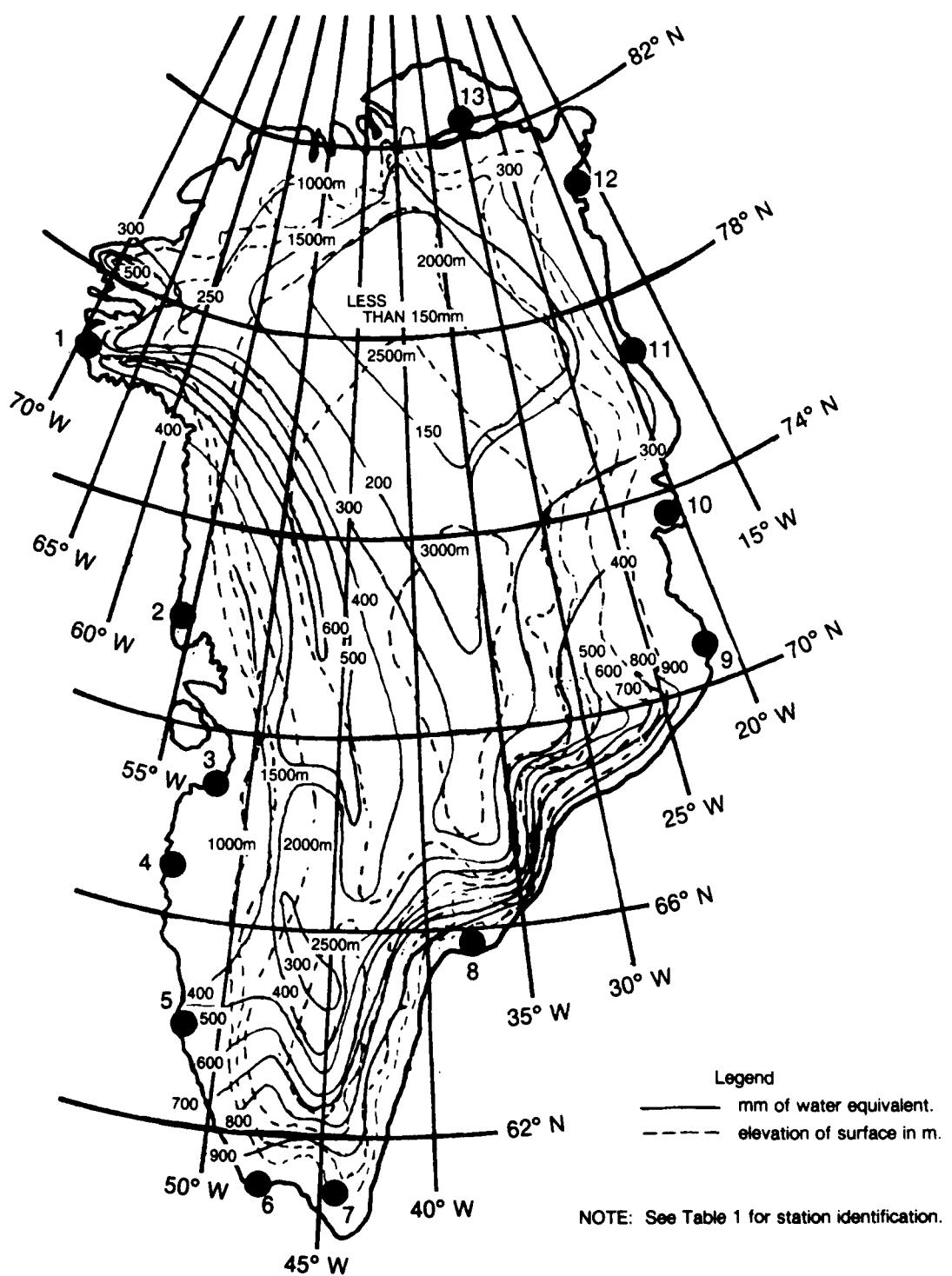


Fig. 1—Mean annual accumulation of snow in Greenland, after Bader [9]

Table 1

STATION LOCATION, ELEVATION, AND MONTHLY AND ANNUAL PRECIPITATION: GREENLAND

Location		Month												Years of Record (a)	Elev. (m)	
		S	O	N	D	J	F	M	A	M	J	J	A			
<i>a. West Coast -- All Latitudes</i>																
1. Thule	mm	16	17	13	6	9	9	5	4	6	6	17	15	122	12	77
(76°31'N 68°44'W)	%	13	14	11	5	7	7	4	3	5	5	14	12	100		
2. Upernivik	mm	30	23	17	11	9	11	9	11	11	9	21	24	186	10-25	35
(72°47'N 56°10'W)	%	16	12	9	6	5	6	5	6	6	5	11	13	100		
3. Jakobshavn	mm	41	29	21	18	10	13	14	15	20	19	35	34	269	19-26	31
(69°13'N 51°03'W)	%	15	11	8	7	4	5	5	6	7	7	13	13	101		
4. Holstensborg	mm	39	37	29	18	17	4	4	8	11	16	44	41	267	6	27
(66°56'N 53°39'W)	%	15	14	11	7	6	2	2	3	4	6	17	15	102		
5. Godthaab	mm	84	71	44	20	26	24	18	25	29	46	59	69	515	19-26	20
(64°10'N 51°45'W)	%	16	14	9	4	5	5	4	5	6	9	12	13	102		
Average:	%	15	13	10	6	5	5	4	5	6	6	13	13			
Accumulated:	%	15	28	38	44	49	54	58	63	69	75	88	101			
<i>b. Southeast Coast -- Near 62°N and 66°N</i>																
6. Ivigtut	mm	162	172	146	77	92	129	87	79	89	96	82	97	1308	19-22	30
(61°12'N 48°10'W)	%	12	13	11	6	7	10	7	6	7	7	6	7	99		
7. Nanortalik	mm	119	125	94	52	64	71	41	59	45	80	53	92	895	9-15	7
(60°08'N 45°13'W)	%	13	14	11	6	7	8	5	7	5	9	6	10	101		
8. Angmagssalik	mm	76	90	86	68	58	82	62	53	54	44	35	62	770	16-26	29
(65°37'N 37°39'W)	%	10	12	11	9	8	11	8	7	7	6	5	8	102		
Average:	%	12	13	11	7	7	10	*7	7	6	7	6	8			
Accumulated:	%	12	25	36	43	50	60	67	74	80	87	93	101			
<i>c. East Coast -- Near 70°N</i>																
9. Scoresbysund	mm	53	56	44	64	29	29	23	21	12	26	38	33	428	17-26	17
(70°25'N 21°58'W)	%	12	13	10	15	7	7	5	5	3	6	9	8	100		
Accumulated:	%	12	25	35	50	57	64	69	74	77	83	92	100			

Table 1 (Continued)

Location		Month												Ann.	Years of Record (■)	Blev.
		S	O	N	D	J	F	M	A	M	J	J	A			
<i>d. East Coast -- Near 74°N, 78°N, and 82°N</i>																
10. Myggbukta (73°29'N 21°34'W)	mm	21	23	31	39	44	30	24	15	9	13	20	29	298	19-20	2
	%	7	8	10	13	15	10	8	5	3	4	7	10	100		
11. Danmarkshavn (76°46'N 19°00'W)	mm	8	8	25	18	31	18	18	3	5	5	1	15	152	2	7
	%	5	5	17	12	20	12	12	2	3	3	1	10	102		
12. Nord (81°36'N 16°40'W)	mm	21	16	35	37	23	20	8	5	3	5	12	19	204	4-5	35
	%	10	8	17	18	11	10	4	3	2	3	6	9	101		
Average:	%	7	7	15	15	15	11	8	3	3	3	5	10			
Accumulated:	%	7	14	29	44	59	70	78	81	84	87	92	102			
<i>e. Miscellaneous</i>																
13. Peary Land (82°10'N 30°30'W)	mm	13	15	3	3	1	5	1	1	1	5	5	5	58	2	9
	%	22	26	5	5	2	9	2	2	2	9	9	9	102		
Accumulated:	%	22	48	53	58	60	69	71	73	75	94	93	102			

Source: References 10,12.

with the depth of snow that is accumulated during a particular month or since the beginning of the current snow season in midsummer.

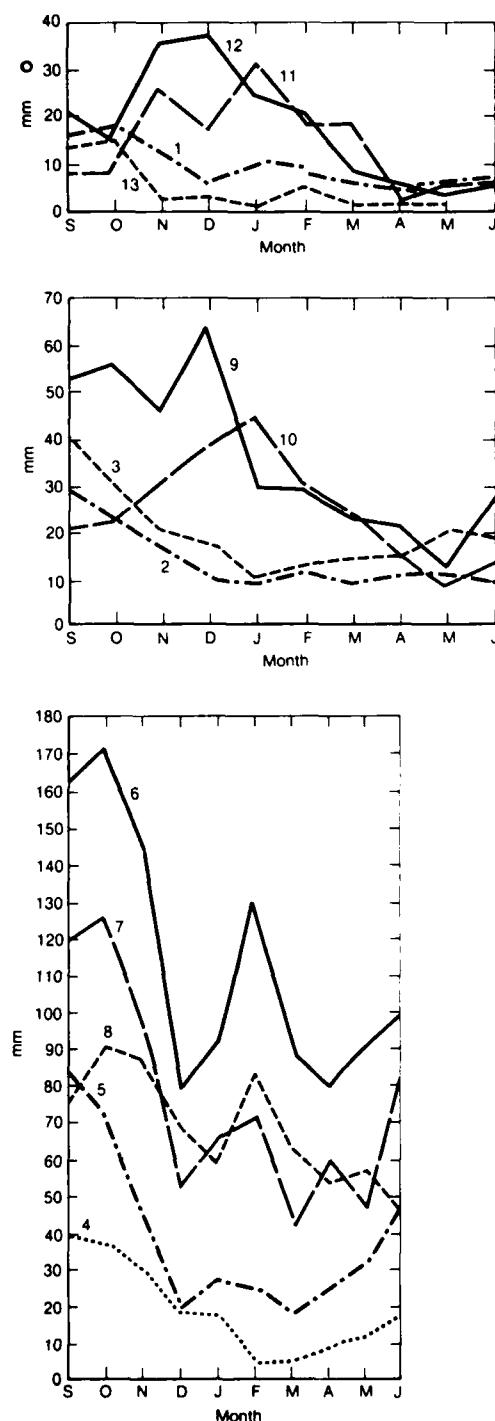
Weather systems, or storms with their low-pressure centers and associated frontal patterns, are the source of most of Greenland's precipitation [10]. For example, southeastern Greenland is near the climatological center of the vigorous Icelandic Low storm track [11], which accounts for the large mean annual accumulation south of 72°N. Greenland also comes under the influence of storms originating in Canada and the United States. As another complication, storms from the west are most active in the late summer and fall, with peaks from July to October (Table 1a), while those affecting the east coast are most active in winter, with peaks from November through January (Table 1c and 1d). Stations south of 66°N (Table 1b) are affected by weather systems from both west and east, resulting in a double precipitation maximum, with

peaks in both October and February. For a better understanding of these variables, the precipitation data in Table 1 were plotted in latitude segments in Fig. 2. These graphs of precipitation show dramatically where the weather systems are most active.

A methodology was devised to calculate the mean monthly snow accumulations at the 34 grid points using only the annual "water equivalent" accumulation (Fig. 1) and the monthly precipitation data (Table 2). These are independent data sources, and there is some apparent disagreement in annual accumulations between them. However, our methodology uses the Bader analysis (Fig. 1) to define the spatial distribution of snow amounts and employs the tabulated data only to define the relative temporal (month by month) distributions.

The station data were sorted by latitude bands as shown in Table 1 and then normalized as a percentage of the annual mean. The start of snow accumulation in Table 1 was based in part on data from Putnins [10], who indicated that actual snow depths are greatest in April and least in August. Putnins also stated that south of the Arctic Circle (about 66°N) snow seldom occurs in June, July, or August (summer) and that to the north up to 84 percent of the precipitation falls by June. This assertion was verified by accumulating the normalized mean-monthly station precipitation beginning in September, normally the first month of snow accumulation (Table 1). Mean monthly snow depths from the Arctic Construction and Frost Effects Laboratory (now CRREL) [2] and Untersteiner [13] further refined the results of Putnins [10]. They showed that at various Northern Hemisphere stations between 64°N and 71°N, there is a rapid decline with latitude in snow accumulation (Fig. 3). On the basis of these data, and the fact that Greenland extends from 60°N to 82°N, we used March as the 100 percent snow-accumulation month between 62°N and 66°N, April between 70°N and 74°N, and May between 78°N and 82°N (Table 2).

Since snow seldom occurs in summer south of about 66°N, May became the first zero-accumulation month between 62°N and 66°N, June between 70°N and 74°N, and July between 78°N and 82°N. The normalized snow-accumulation data shown in Table 2 were further refined by dividing the latitude bands into west and east sectors through Greenland's highest



Latitude Zone 78°-82° N

Station Number	Station Name	Coast	Annual Precipitation (mm)
12.	Nord	E	204
11.	Danmarkshavn	E	152
13.	Peary Land	N	58
1.	Thule	W	122

Latitude Zone 70°-74° N

Station Number	Station Name	Coast	Annual Precipitation (mm)
9.	Scoresbysund	E	428
10.	Myggbukta	E	298
3.	Jakobshavn	W	269
2.	Upernivik	W	186

Latitude Zone 62°-66° N

Station Number	Station Name	Coast	Annual Precipitation (mm)
6.	Ivigtut	S	1308
7.	Nanortalik	S	895
8.	Angmagssalik	S	770
5.	Godthaab	W	515
4.	Holstenborg	W	267

NOTE: See Table 1 for station identification.

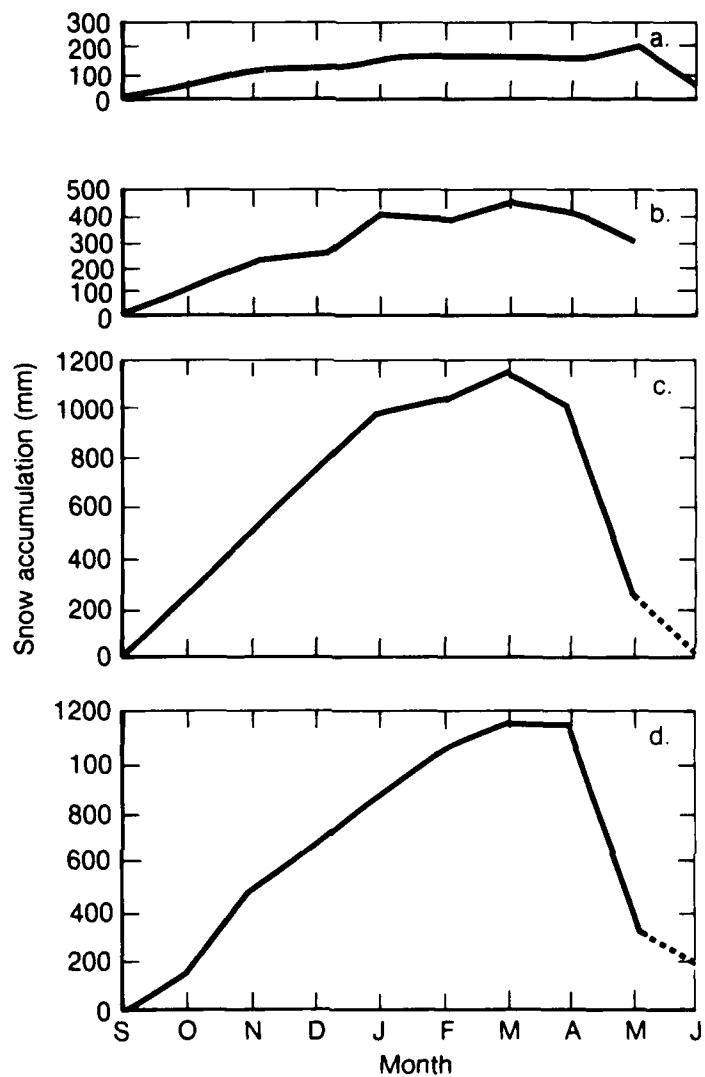
Fig. 2—Monthly precipitation at Greenland stations by latitude

Table 2

NORMALIZED MONTHLY SNOW ACCUMULATION: GREENLAND
(In percent)

Location	Month											
	S	O	N	D	J	F	M	A	M	J	J	A
a. West Coast:												
Accumulated	15	28	38	44	49	54	58	63	69	75	88	101
Normalized -- 62°N & 66°N	26	48	65	76	85	93	100	50	0			
Normalized -- 70°N & 74°N	24	44	60	70	78	86	92	100	50	0		
Normalized -- 78°N & 82°N	22	41	55	64	71	78	84	91	100	50	0	
b. Southeast Coast:												
Accumulated	12	25	36	43	50	60	67	74	80	87	93	101
Normalized -- 62°N & 66°N	18	37	54	64	75	90	100	50	0			
c. East Coast (Southern):												
Accumulated	12	25	35	50	57	64	69	74	77	83	92	100
Normalized -- 70°N	16	34	49	68	77	87	93	100	50	0		
d. East Coast (Northern):												
Accumulated	7	14	29	44	59	70	78	81	84	87	92	102
Normalized -- 74°N	9	17	36	54	73	86	96	100	50	0		
Normalized -- 78°N & 82°N	8	17	35	52	70	83	92	96	100	50	0	

elevation at 40°W longitude. Stations 1 through 5 typified the west, where precipitation peaks in late summer and fall; stations 6, 7, and 8 typified the southeast, where precipitation peaks in October and February; and stations 9 through 12 typified the east, where precipitation peaks in winter (Table 2 and Fig. 4). In the east, separate curves were used at 70°N and 74°N from September to April, and a common curve was used from April to June, the month of zero snow accumulation (Fig. 4). These curves were then used directly to compute the monthly snow depths at the 34 grid points across Greenland's ice cap from the mean annual accumulation curves (Fig. 1). No observed monthly snow-depth data were available for the ice cap.



SOURCE: References 2, 10, 13.

Station	Location	Elevation (m)	Years of Record
a. Ice Station A	82°–86° N, 113°–176° W		1
b. Point Barrow, Alaska	71° 23' N, 156° 17' W	4	3–6
c. Turukhansk, USSR	65° 47' N, 87° 57' E	45	21
d. Markovo, USSR	64° 41' N, 170° 25' E	20	16

Fig. 3—Mean monthly snow accumulation at various stations

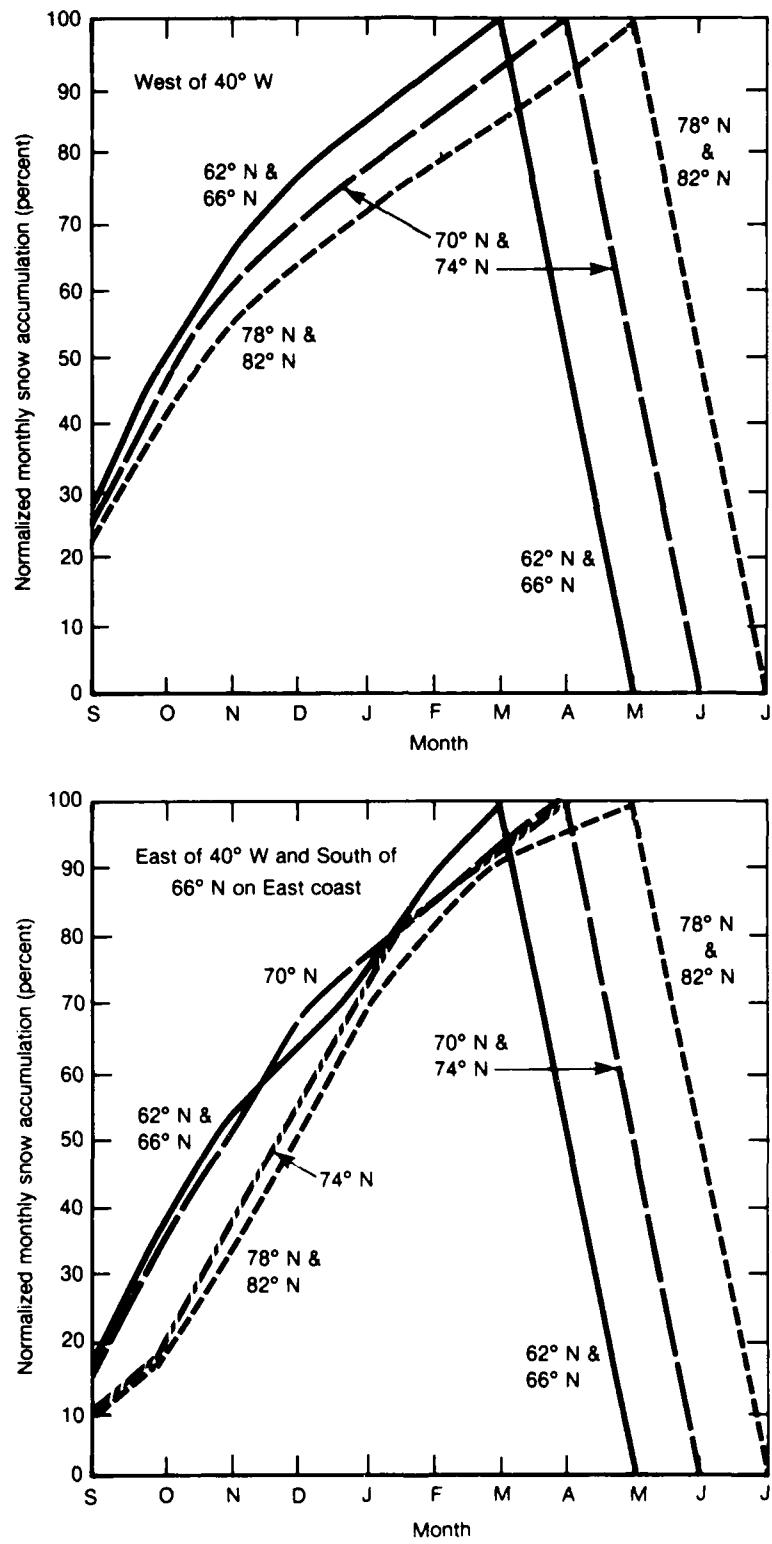


Fig. 4—Normalized monthly snow accumulation in Greenland
(Percent)

The snow accumulation values obtained were in millimeters of equivalent water depth and had to be converted to millimeters of snow. To determine the conversion factor, snow-cover densities from 27 stations in North America and Greenland prepared by Bilello [14] were used. Densities ranged from 0.199 g cm^{-3} at Fairbanks, Alaska, to 0.363 g cm^{-3} at Isachsen, Northwest Territory, with an arithmetic average of 0.282 and a median of 0.279 g cm^{-3} for the 27 stations. With water at 1.0 g cm^{-3} , this indicates a rough conversion factor for accumulated snow of 3 millimeters of snow to 1 millimeter of water. Fresh fallen snow, according to Huschke [15] usually has a much lower density of 0.07 to 0.15 g cm^{-3} , for a ratio of about 10:1.

ARCTIC BASIN

The rest of the Arctic, like Greenland, is data-sparse. It covers the grid points north of 70°N in the simulations. Professor Untersteiner at the University of Washington in conversations and in Ref. 13 and Vowinckel and Orvig in Ref. 16 have indicated that the annual precipitation over the polar ocean is meager. For example, Vowinckel and Orvig state that the probable average annual water equivalent snow accumulation over the central polar ocean is about 135 mm. Untersteiner [13] states that an accumulation of 210 mm was recorded for Ice Station A (between 80°N and 85°N at about 160°W) for the period from September 1957 to May 1958 (Table 3 and Fig. 5). Precipitation is mainly in the form of snow, with its maximum in autumn and late spring and its minimum in winter. May is the month of maximum accumulation.

Table 3

DRIFT STATION SNOW DEPTHS: 1957-1958 (IGY)

Date	U.S. Station "A"				USSR "North Pole 6"				USSR "North Pole 7"			
	Approx. Lat.	Approx. Long.	Dept ⁿ	% of Annual	Approx. Lat.	Approx. Long.	Dept	% of Annual	Approx. Lat.	Approx. Long.	Dept	% of Annual
July 1957	83.0 N	165.0 W	0	0	78.1 N	158.2 E	40	0	84.5 N	169.8 E	40	3 (-3)
Aug. 1957	84.5 N	170.0 W	0	0	77.4 N	161.0 E	210	28	85.9 N	178.5 E	10	4 (-2)
Sep. 1957	85.5 N	170.0 W	26	19	77.3 N	164.0 E	330	45	87.0 N	166.4 E	60	13
Oct. 1957	85.0 N	174.0 W	130	57	77.1 N	161.9 E	550	74	86.8 N	168.7 E	300	62
Nov. 1957	84.3 N	165.0 W	110	52	77.6 N	156.9 E	550	74	86.1 N	178.4 E	260	56
Dec. 1957	84.0 N	160.0 W	130	82	78.3 N	152.7 E	560	76	-	-	-	-
Jan. 1958	83.7 N	157.0 W	150	71	79.0 N	153.1 E	620	84	85.7 N	161.5 W	180	84
Feb. 1958	83.9 N	152.0 W	150	71	79.7 N	153.1 E	730 ^b	99	85.9 N	155.8 W	310 ^a	63
Mar. 1958	84.0 N	151.0 W	150	76	80.4 N	151.9 E	720	97	86.1 N	152.1 W	320	71
Apr. 1958	79.0 N	161.0 W	130	91	81.1 N	149.0 E	740	100	86.5 N	149.2 W	400	89
May. 1958	84.0 N	145.0 W	210	100	81.0 N	147.2 E	750	-6	86.4 N	147.8 W	430	100
June 1958	84.0 N	142.0 W	50	-76	82.3 N	141.7 E	440	-45	86.8 N	139.8 W	50	-88

Source: Reference 13.

^aTotal depth of new snow per month.

^bApproximate value.

Most of the precipitation in the Arctic was assumed to be of cyclonic origin [16]. Areas affected by individual storms, however, are not very large, and the active life of the surface cyclone is usually short. An annual storm-track map (Fig. 6) was used as a basis for extending local coastal snow-depth data for North America and the Soviet Union toward the pole. A limit on this poleward extension was made with accumulation measurements taken by observers aboard the U.S. Drifting Station A and the USSR drift stations North Pole 6 and North Pole 7 during the International Geophysical Year of 1957-58 [13] and from conversations with Prof. Untersteiner. This combination lent realism to the character of the isopleths. However, the lack of real data makes

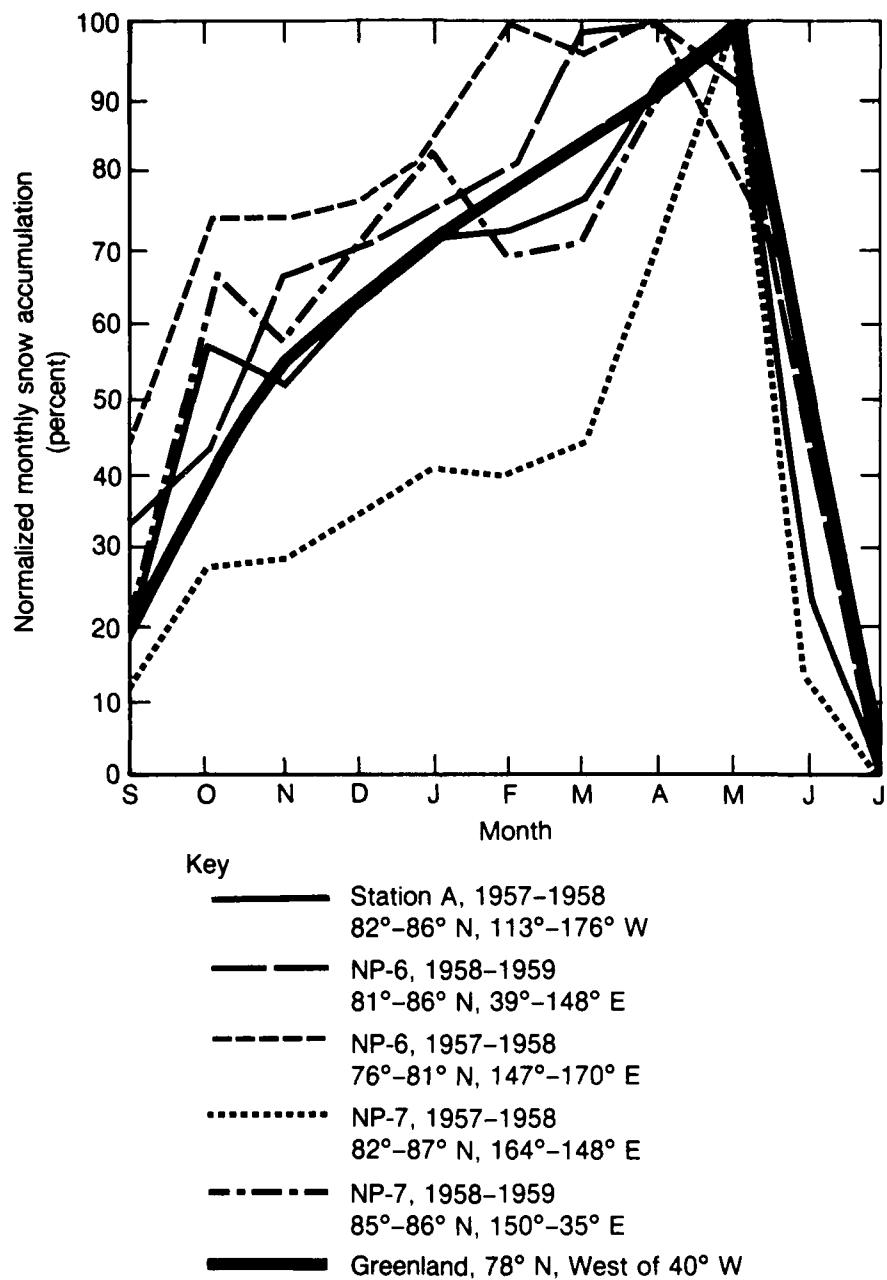


Fig. 5—Normalized monthly snow accumulation at Arctic drift stations
(Percent)

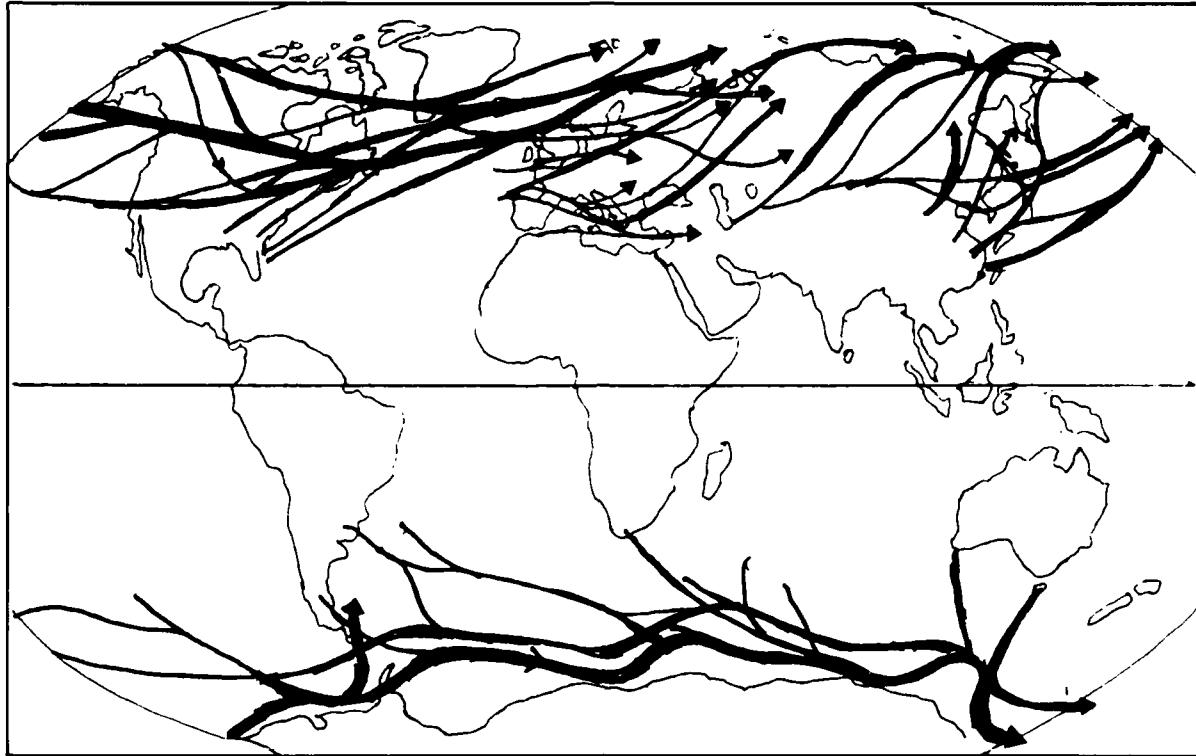
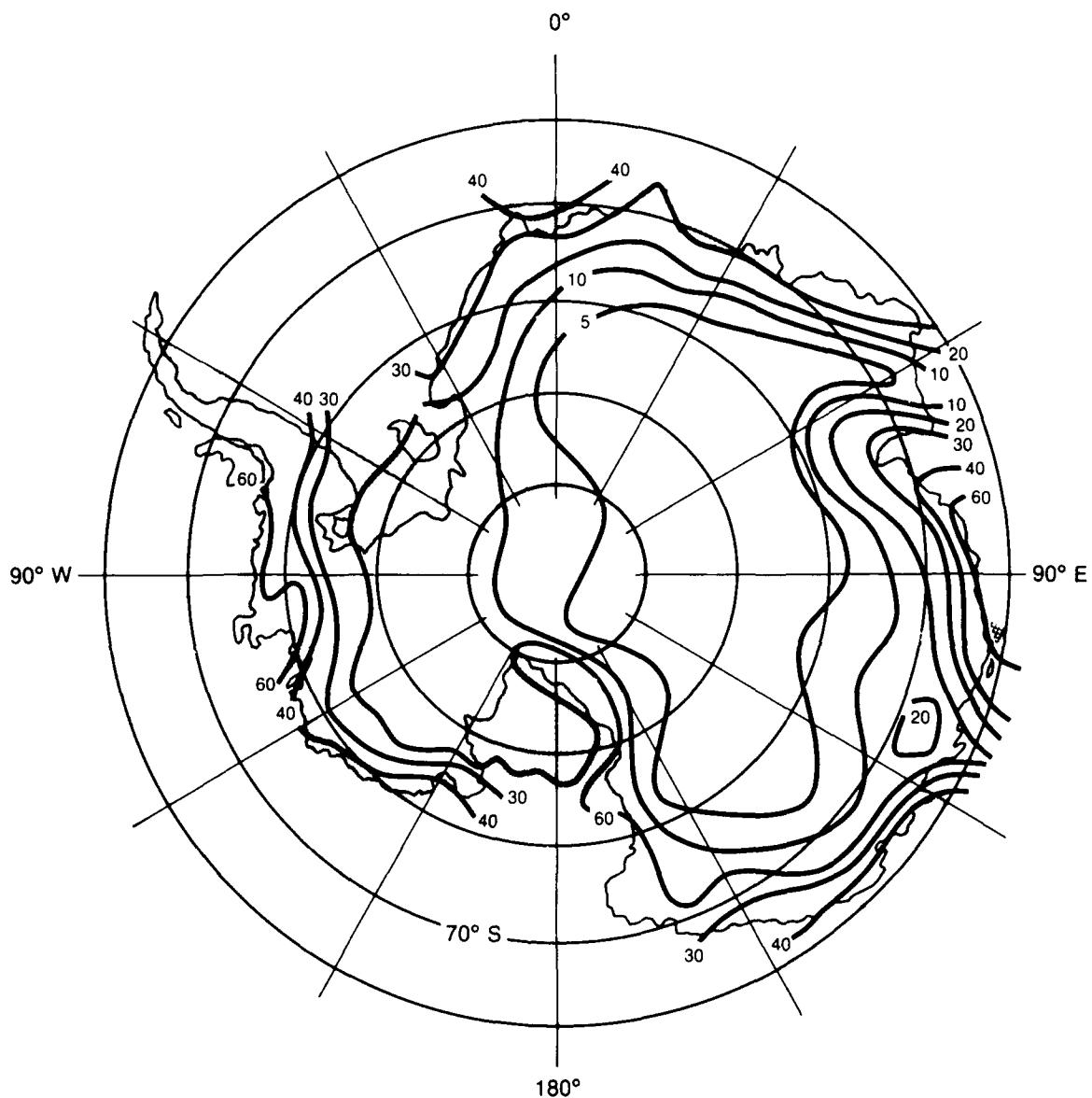


Fig. 6—Annual storm tracks, after Bartholomew [17]

the mean accumulation amounts at certain grid points over the Arctic ice cap questionable.

ANTARCTICA

Snow accumulation data for the Antarctic continent were available only as an average annual accumulation in g cm^{-2} ; see Fig. 7, which was taken from Schwerdtfeger [18]. Also, Schwerdtfeger emphatically stated that this accumulation results not only from solid precipitation due to the synoptic process but from evaporation, deposition (hoarfrost), and the effects of snow drift as well. In the inland plateau region, a major portion of the snow and ice is *not* brought about by precipitation.



SOURCE: Schwerdtfeger [18].

Fig. 7—Average annual snow accumulation over Antarctica
(g cm^{-2})

For example, Schwerdtfeger states that in 1967 and 1968, respectively, there were 40 and 62 days with observed snowfall (never more than "traces"), but there were 317 and 314 days with ice crystals floating in the air. For the coastal regions and the lower, steeper parts of the glacial slopes, the relation between precipitation and accumulation is much more uncertain because of the direct influence of cyclonic activity. It can vary from place to place due to wind, local terrain features, and observed surface characteristics, including temperatures above the freezing point. Therefore, stratigraphic (core-type) measurements at many spots surrounding permanent stations and during traverses have been the main source of information. According to Schwerdtfeger, the regional distribution of average annual net accumulation of snow is relatively well established.

The strong temperature contrast in the subpolar belt between the ice cap and the open ocean leads to the formation of cyclonic storms, which are the major source of snowfall; note Fig. 6. The coastal stations generally receive snow throughout the year [19]. They report late summer and autumn maxima, but a large portion of the precipitation can occur during the winter months. Although the storms are strongest in the subpolar belt, daily weather maps show that they do move far inland [18] and so are instrumental in the meridional exchange of air masses and transport of moisture from the oceanic to the continental regions. Thus, although most of the snow falls within a few hundred kilometers of the coast line [20], the downward transport of the atmospheric moisture brought in by the storm systems leads to the formation of ice particles and the deposition of hoarfrost that makes up a major portion of the accumulation inland [18]. In a rough sense, therefore, the inland and coastal accumulations of snow are related. We thus decided to use mean monthly snowfall amounts at the four coastal stations with the most complete records to prorate the average annual accumulation (Table 4).

The monthly mean snowfall at the coastal stations was converted to a percentage of the annual snowfall and then averaged by month for the four stations. December and January are the summer months in

Table 4

MONTHLY MEAN SNOWFALL AMOUNTS, ANTARCTICA
(In millimeters)

Station	Season ¹ and Month												Ann.	Years
	1 J	2 F	3 M	4 A	5 M	6 J	7 J	8 A	9 S	10 O	11 N	12 D		
1. Ellsworth (50°W)	mm: 64	38	64	140	48	61	51	51	69	99	119	51	803	4-5
	%: 8	5	8	17	6	8	6	6	9	12	15	6	100	
2. Hallett (180°)	mm: 201	251	389	145	201	104	226	135	84	81	18	10	1915	7-8
	%: 11	13	20	8	11	6	12	7	4	4	1	1	100	
3. Little America (170°W)	mm: 104	338	414	198	272	213	168	122	234	211	117	241	2548	2-3
	%: 4	13	16	8	11	8	7	5	9	8	5	10	100	
4. Wilkes (100°E)	mm: 137	53	427	277	343	297	325	211	386	292	234	79	3043	6-7
	%: 5	2	14	9	11	10	11	7	13	9	7	3	100	
Average Accumulation	%: 7	8	15	11	10	8	9	6	9	8	7	5		
	%: 7	15	30	41	51	59	68	74	83	91	98	103	100	

Source: Reference 19.

¹ 1 = summer; 2 = fall; 3 = winter; 4 = spring.

Antarctica, but snowfall observations suggest that the annual accumulation begins as early as January. It increases steadily, reaching a maximum in November, and then decreases to zero by the following January (Fig. 8). With this methodology, 68 percent of the average annual accumulation was collected by the end of July (mid-winter) and 100 percent by the end of November. This would not hold true inland over the plateau, which lies generally above 2000 m. It probably does apply in the coastal areas, where liquid precipitation is occasionally found, and the small amount of snowfall indicated for December (Table 4) does not accumulate because of surface temperatures occasionally above freezing.

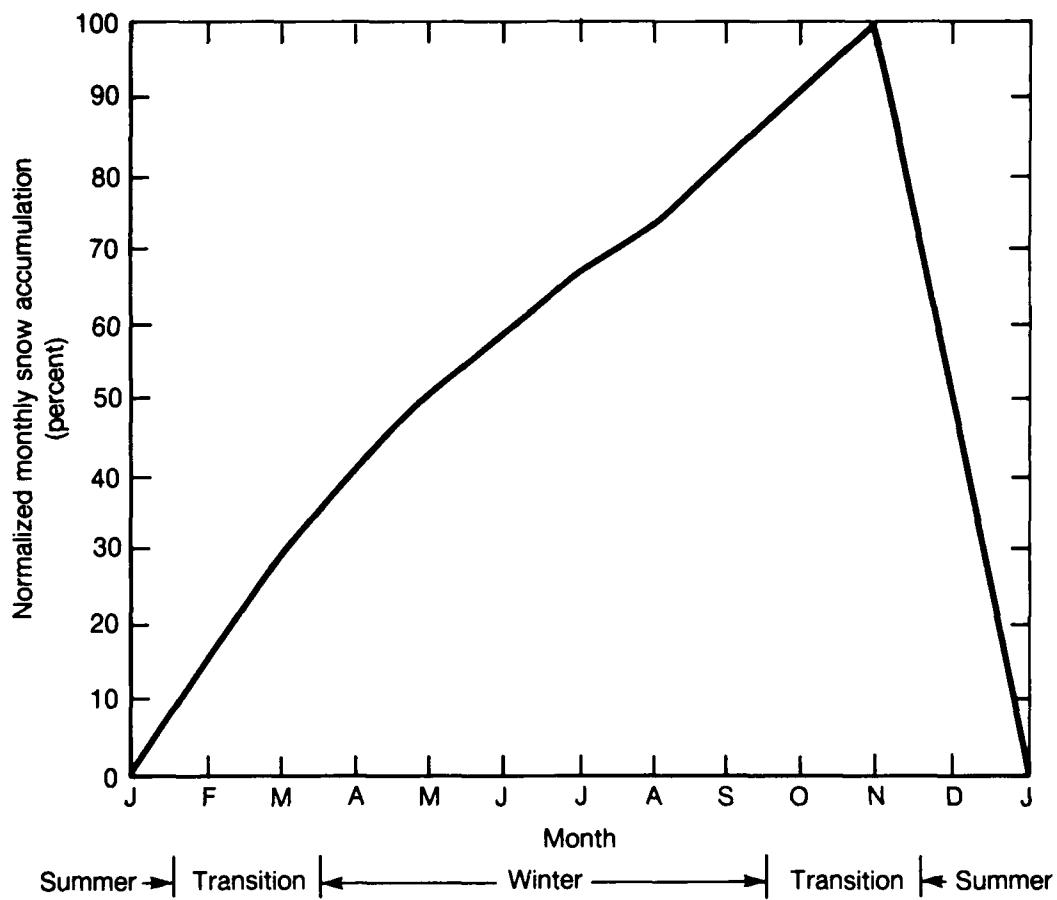


Fig. 8—Monthly snow accumulation over Antarctica
(Percent of annual)

After January, as ice begins to reform around the continent, the area covered by new snow increases. Ice limits for each month were used as the "zero-accumulation" line around the continent. Isopleths were drawn between the zero-accumulation line and known snow depths inland for determining grid-point values over this new ice. In the middle of the continent, about 150 mm of snow and rime accumulate annually throughout the entire plateau. No effort was made to scale down this area toward the central plateau.

To convert the average annual accumulation in g cm^{-2} to millimeters of snow, the basic density value of 1 g cm^{-3} for water was used. One year of data from Little America gave a snow density of 0.35, so the rule of 3 millimeters of snow for 1 millimeter of water, used in the Arctic, was also applied to the Antarctic.

CHINA

China, with grid points from 30°N to 46°N and from 75°E to 115°E in the RAND model, can be divided into three areas for the development of a snow-depth climatology. They are Tibet in the southwest, Sinkiang in the northwest, and the North-Central portion, where the mountains slope gradually eastward to the coastal plain.

During the snow season, or the period of the northeast monsoon from November to March, China is under the influence of the Siberian High [11]. By January this High becomes nearly stationary over Mongolia and is quite strong, with a central pressure greater than 1030 mb. The northeast monsoon is so called because it was originally studied over India, where the winter season winds originating in the Siberian High come from the northeast. Over much of China, the monsoon flow is from the north or northwest [21]. The Siberian High is the source of dry, stable, continental air that spreads over China and all of Southeast Asia.

The only moisture available for snow at this time comes from an occasional cyclonic storm that can bring in maritime air from the east or southeast. Most cyclonic storms, however, are deflected by the enormous mountain ranges that bound China to the west and southwest. Storms from the Mediterranean area are deflected southeastward by the mountains of Turkey and Iran well to the west and by the Himalayas in the south. Storms from Western Europe are deflected northeastward by the Pamir and Tien Shan ranges as well as by the nearly stationary Siberian High. In general, the total accumulation is less than 75 mm in the valleys where the snow is regularly measured during the period of the northeast monsoon. The exception seems to be through northern Sinkiang, where fronts occasionally extend southward from the more

active cyclonic storm systems moving across Siberia. These storms leave up to 180 mm of accumulated snow in an average winter season. In sum, throughout China, except on the higher mountain slopes and peaks, measured snow amounts are small during the snow season.

Since mean-monthly snow-accumulation data were not available for China, a simple methodology was devised to estimate any possible accumulation. It was based on the mean-monthly precipitation (water equivalent, in millimeters) and "mean-daily maximum" temperature ($^{\circ}\text{C}$) each month, published in an Atlas of Chinese Climatology [3]. In the areas where mean-daily maximum temperatures averaged below 0°C during the month, precipitation was assumed to be the water equivalent of snow. As discussed previously [14], "old" or accumulated snow has a density of approximately 0.3; therefore, the precipitation amounts were multiplied by three (except where noted) to give the snow depth. These amounts were then accumulated during the month when temperatures remained around 0°C or below. Any temperature below about 2°C or 3°C was assumed to give a potential for snow. It was also assumed that all temperatures were measured in a thermoscreen about 1.5 meters above the ground. At stations where the temperatures averaged well below 0°C for the month, snow depth developed from the water-equivalent precipitation was adjusted empirically. These precipitation data were multiplied by as much as six or even eight, since the snowfall would not compact fast and would remain less dense or more fluffy. Also, a careful interpolation was made between recording stations to determine the final grid-point value. This methodology gave snow depths that were, in general, compatible with the surrounding data from the Corps of Engineers study [2].

Tibet

Tibet, located in southwest China, with RAND grid points from 30°N to 38°N and 80°E to 100°E , has a mean elevation of 4000 meters, with many snow-covered peaks and snow fields extending to 6000 meters or more. Across Tibet, data on the mean number of days with snow cover are very sparse, and all the stations evaluated are at the lower valley levels where the people live. For the analyses, there were 12 grid

points on the RAND 4° latitude by 5° longitude grid and seven weather reporting stations (all below 3700 meters) from the Atlas of Chinese Climatology [3]; see Table 5a. The precipitation and temperature values in Table 5b show that any possible monthly snow accumulations at Tibet's weather reporting stations are 25 mm or less. This is true even though the precipitation total at Station A, for example, was multiplied by six because of the very low average daily maximum temperature in December and January. Therefore, since most of what falls is quickly evaporated in the dry air or blown into crevasses and low places by the almost constant wind, "no" snow accumulation was shown at the grid points from November through March across Tibet (see the appendix). It must be remembered, however, that snow falls year around on the higher peaks, which are usually well above the freezing level.

Sinkiang

Sinkiang in northwest China, with grid points from 30°N to 46°N and 75°E to 95°E , is surrounded by mountains, including the Altin Tagh in the south, the Pamirs and Tien Shan in the west, and the Altai range in the northeast. These ranges encompass the Dzungaria Basin in the northern portion and the Tarim Basin and the Takla Makan Desert in the southern portion of Sinkiang. The reporting stations are all below 1500 meters; see Table 6a. For the analysis, there were 11 grid points on the RAND 4° latitude by 5° longitude grid and nine reporting stations from the Atlas of Chinese Climatology [3] to use for the interpolations; see Table 6c.

Most of the snow cover is thin at the reporting points during the snow season from November to March. However, persistent below-freezing temperature within the dry continental air mass, as shown at Stations A and B in Table 6b, causes the snow from an occasional weather system to remain on the ground. The grid-point tabulations in the appendix reflect the influence of the weather systems that move across northern Sinkiang and the persistent low temperatures. Most locations in the higher mountains of west-central Sinkiang and the Dzungaria Basin in the north report snow cover continuously from November to March, for an average of 115-150 days per year. Resulting snow depths are 300-600 mm

Table 5
STATION SUMMARY FOR TIBET AND ENVIRONS

a. Station Locations

Station	Lat.	Long.	Blev. (m)
A. Huanghoyen (Mado) [Tsinghai]	34°57' N	98°08' E	4221
B. Katmandu [Nepal]	27°42' N	85°22' E	1336
C. Leh [Kashmir]	34°09' N	77°34' E	3514
D. Lhasa [Tibet]	29°42' N	91°08' E	3659
E. Tulanssu [Tsinghai]	37°01' N	98°46' E	2985
F. Yushu [Tsinghai]	33°06' N	96°45' E	3704
G. Ch'ienmo (Cherchen) [Sinkiang]	38°08' N	85°32' E	966

b. Precipitation and Temperature

Sta.	November			December			January			February			March		
	P ^a	S ^b	T ^c	P	S	T	P	S	T	P	S	T	P	S	T
A.	3	8	-1	5	30	-7	5	30	-8	5	15	-4	8	15	1
B.	5		23	8		19	25		18	23		20	28		24
C.	< 1		6	5	15	3	10	3	0	8	23	2	8		7
D.	10		13	< 1		9	< 1		8	5		9	13		12
E.	3		6	0.3	0.8	3	< 1	4	0	3	8	2	5		7
F.	3		8	5	15	2	8		5	3		8	8	15	1
G.	3		8	< 1	4	2	< 1	4	0	< 1		7	0		16

^aPrecipitation, mean monthly water equivalent (millimeters).

^bSnow depth [precipitation times a multiple; see text] (millimeters).

^cTemperature, mean daily maximum (°C).

c. Stations Closest to Affected Grid Points (Appendix)

Lat.	Longitude				
	80°E	85°E	90°E	95°E	100°E
38°N			G	E	E
24°N	C	C	F	F	A
30°N	B	B	D	D	

Source: References 3, 22.

Table 6
STATION SUMMARY FOR SINKIANG

a. Station Locations

Station	Lat.	Long.	Elev. (m.)
A. Zaysan [U.S.S.R.]	47°28' N	84°55' E	603
B. Qitai (Ch'i-t'ai)	44°01' N	89°34' E	794
C. Ining (Kuldja)	43°57' N	81°26' E	664
D. Kugar (K'u-ch'e)	41°45' N	83°04' E	1100
E. Yenchi (Karashahr)	42°03' N	86°34' E	1038
F. Turfan	42°56' N	89°14' E	35
G. Tun-huang	40°08' N	94°47' E	1139
H. Kashgar (Ko-shih)	39°31' N	75°45' E	1410
I. Khotan (Ho-tien)	37°07' N	79°55' E	1387

b. Precipitation and Temperature

Sta.	November			December			January			February			March		
	P	S ^b	T ^c	P	S	T	P	S	T	P	S	T	P	S	T
A.	18	53	-8	13	91	-15	8	114	-14	8	137	-12	10	168	-2
B.	15		1	10	30	-7	5	46	-11	10	76	-6			2
C.	38		3	23	69	-5	8	91	-4			2			7
D.	8		?	3	8	-3	1	11	-3			3			13
E.	5		?	3	8	-1	15	46	-3			4			13
F.	< 1		9	3	8	0	3	8	-4			6			17
G.	< 1		9	3	8	1	1		1			6			14
H.	5		12	8	3	15		1				6			13
I.	< 1		10	< 1	4	< 1		1				6			16

^aPrecipitation, mean monthly water equivalent (millimeters).

^bSnow depth (precipitation times a multiple; see text) (millimeters).

^cTemperature, mean daily maximum (°C).

c. Stations Closest to Affected Grid Points (Appendix)

Lat.	Longitude				
	75°E	80°E	85°E	90°E	95°E
46°N		C	A	B	
42°N	C	D	B	F	G
38°N	H	I	D,E	.	

in these areas, and up to 150 mm in parts of the Tarin Basin in the south. There is an increase in snow depth north of 42°N between 75°E and 95°E.

North-Central China

North-Central China lies south of Mongolia and covers 10 grid points in the RAND model and 12 weather reporting stations from 34°N to 42°N and from 100°E to 115°E; see Table 7a and 7c. The area slopes gradually eastward to the coastal plains and is drained by the extensive Huang Ho and Yangtze river systems, which flow eastward into the Yellow Sea. These major rivers are fed by an enormous amount of tropical rain during the wet summer monsoon from May to September, when the surface flow is from the southeast [21]. During the winter monsoon from November to March, the surface air flow is from the northeast over North-Central China, and the weather is dry, cold, and relatively clear; see Table 7b.

There is very little snow over North-Central China during the winter monsoon. As in the case of Sinkiang, migratory weather systems from the west are deflected and degraded by the enormous mountain ranges to the west and north, by the great Gobi Desert, and by the semi-permanent Siberian High over Mongolia [11]. This is the dry season. The scanty precipitation, which often falls as snow, is light and infrequent. In the southeast portion of this area, less than 25 mm of precipitation (water equivalent) is reported at most stations from November to March. The total snow depth decreases inland, where the northern plains are the driest region of North-Central China. In general, there is snow cover inland on about half of the days in the worst months. Snow does not often remain on the ground in the coastal locations south of 37°N or in the sheltered valleys inland. At these locations there are only one or two days with snow cover during the worst months. In the north, the temperatures remain well below 0°C during December, January, and February, but it is much warmer in the south. Therefore, for the interpolations, when considering both precipitation and temperature, snow depths at the grid points along 42°N, as shown in the appendix, reflect the four station values, whereas zero accumulation is shown at the grid points along 34°N. See Table 7b and 7c.

Table 7
STATION SUMMARY FOR NORTH CENTRAL CHINA

a. Station Locations

Station	Lat.	Long.	Elev. (m.)
A. Chiuchüan	39°50' N	98°15' E	1543
B. Huhohao't'e (Kueisui)	40°49' N	111°41' E	1062
C. Tolun (Dolon Nor)	42°15' N	116°15' E	124
D. Changchiak'ou (Kalgan)	40°50' N	114°58' E	760
E. Chungning (Zhongning)	37°29' N	105°40' E	1186
F. Yulin	38°14' N	109°42' E	1958
G. Suite	34°25' N	109°57' E	2074
H. Shinchiachuang (Shihmen)	38°04' N	114°26' E	82
I. Wutu	34°23' N	104°41' E	1090
J. Anyang	36°07' N	114°22' E	76
K. Pohsien	33°53' N	115°47' E	37
L. Yin-ch'uan	38°29' N	106°13' E	1113

b. Precipitation and Temperature

November				December				January				February				March			
Sta.	P ^a	S ^b	T ^c	P	S	T	P	S	T	P	S	T	P	S	T	P	S	T	
A.	3	6	3	8	-1	< 1	4	0	3	8	3	5	5	10					
B.	8	4	10	30	-2	5	46	-4	8	63	-1	5	5	8					
C.	8	23	1	5	15	-10	5	33	-12	3	38	-7	8	23	2				
D.	5	15	1	3	15	-10	3	30	-12	5	38	-7	5	15	2				
E.	3	6	< 1	3	-1	3	11	-2	3		4	5	5	11					
F.	13	8	3	8	1	3	8	0	3		4	8	8	11					
G.	5	8	15		1	8	15	0	8		4	10	10	11					
H.	15	12	3		7	3		3	5		6	5	5	15					
I.	8	14	< 1		9	3		8	5		11	10	10	17					
J.	30	14	13		9	5		8	20		12	28	28	17					
K.	51	> 0	36		> 0	33		> 0	25		> 0	15	15	> 0					
L.	8	6	> 1	4	-	> 1	4	-2	5		4	5	5	11					

^aPrecipitation, mean monthly water equivalent (millimeters).

^bSnow depth [precipitation times a multiple; see text] (millimeters).

^cTemperature, mean daily maximum (°C).

Table 7 (Continued)

c. Stations Closest to Affected Grid Points (Appendix)

Lat.	Longitude			
	100°E	105°E	110°E	115°E
42°N	A	A,B	B	C,D
38°N		B,L	F,G	H
34°N		I	J	J,K

Source: References 3, 22

42°N, as shown in the appendix, reflect the four station values, whereas zero accumulation is shown at the grid points along 34°N. See Table 7b and 7c.

III. CONCLUSION

The data presented here were assembled and processed for a particular purpose: to support the numerical general circulation model used in the RAND climate dynamics project. They served that purpose but were never separately documented. The data base remained on file, however, and in the years since the ending of the climate dynamics project, it has been found to be of use to a number of researchers. Although other studies of snow depth and extent have since been made and published elsewhere, the RAND data base is so comprehensive that it remains a valuable research resource. For that reason, it was decided to document it at this time to make it more readily available and understandable to anyone having need for it.

The tabulated snow-accumulation values shown in the appendix are available on tape from the Data Facility within the RAND Computer Information Systems Department as Data Base No. 469. The tabulations for the RAND grid have also been interpolated to a 5° by 5° grid, and a tape of these interpolated values, identified as Data Base No. 366, is also available from the Data Facility.

Some more recent studies of snow cover by other agencies may be found in Refs. 30 through 35. These reports present different types of snow data and do not supplant the data base given here: they represent useful supplement to it.

Appendix

GLOBAL GRID-POINT TABULATIONS

Tables A.1 through A.12 are computer-generated tabulations of mean snow accumulation in millimeters for each point of the 4° latitude by 5° longitude grid for each of the 12 months as of the last day of each month. The value "0" is shown for grid points at which no snow is reported or for which no data could be generated, and "1" is shown for grid points at which a very small accumulation (a "trace") is reported. The values for the poles are indicated at each of the longitudes, although each pole is, in fact, but a single grid point.

An attempt was made to produce contour maps of snow accumulation for the mid-season months, but the severe crowding and fine detail of contours associated with the geography of certain areas precluded the construction of reproducible maps of manageable size. Hence, blank outline maps of the Northern and Southern Hemispheres in polar stereographic projection showing the location of each grid point are given as Figs. A.1 and A.2. These, in conjunction with Tables A.1 through A.12, will enable the reader to visualize the geographic distribution of snow accumulation.

Table A.1a

ACCUMULATION (mm) -- JANUARY

Table A.1b

ACCUMULATION (mm) -- JANUARY

Table A.1c

ACCUMULATION (mm) -- JANUARY

Table A.1d

ACCUMULATION (■) -- JANUARY

Table A.2a

ACCUMULATION (mm) -- FEBRUARY

Table A.2b

ACCUMULATION (mm) -- FEBRUARY

Table A.2c

ACCUMULATION (mm) -- FEBRUARY

Table A.2d

ACCUMULATION (ss) -- FEBRUARY

Table A.3a

ACCUMULATION (mm) -- MARCH

Table A.3b

ACCUMULATION (mm) -- MARCH

Table A.3c

ACCUMULATION (mm) -- MARCH

Table A.3d

ACCUMULATION (■) -- MARCH

Table A.4a

ACCUMULATION (in) -- APRIL

Table A.4b

ACCUMULATION (mm) -- APRIL

Table A.4c

ACCUMULATION (■) -- APRIL

Table A.4d

ACCUMULATION (■) -- APRIL

Table A.5a

ACCUMULATION (II) -- MAY

Table A.5b

ACCUMULATION (ns) -- MAY

Table A.5c

ACCUMULATION (■) -- MAY

Table A.5d

ACCUMULATION (mm) -- MAY

Table A.6a

ACCUMULATION (mm) -- JUNE

Table A.6b

ACCUMULATION (aa) -- JUNE

Table A.6c

ACCUMULATION (mm) -- JUNE

Table A.6d

ACCUMULATION (■) -- JUNE

Table A.7a

ACCUMULATION (mm) -- JULY

Table A.7b

ACCUMULATION (mm) -- JULY

Table A.7c

ACCUMULATION (mm) -- JULY

Table A.7d

ACCUMULATION (BB) -- JULY

Table A.8a

ACCUMULATION (mm) -- AUGUST

Table A.8b

ACCUMULATION (mm) -- AUGUST

Table A.8c

ACCUMULATION (mm) -- AUGUST

Table A.8d

ACCUMULATION (mm) -- AUGUST

Table A.9a

ACCUMULATION (mm) -- SEPTEMBER

Table A.9b

ACCUMULATION (mm) -- SEPTEMBER

Table A.9c

ACCUMULATION (■) -- SEPTEMBER

Table A.9d

ACCUMULATION (■) -- SEPTEMBER

Table A.10a

ACCUMULATION (mm) -- OCTOBER

Latitude	Longitude																	
	180	175W	170W	165W	160W	155W	150W	145W	140W	135W	130W	125W	120W	115W	110W	105W	100W	95W
90N	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
86N	97	91	91	91	91	91	91	91	91	89	89	81	81	81	81	81	81	81
82N	142	132	122	117	112	112	102	102	102	99	249	86	81	81	71	71	71	71
78N	152	147	142	137	132	127	122	117	112	112	104	102	91	81	81	81	127	178
74N	112	122	112	117	117	117	114	112	107	104	102	81	51	71	81	102	203	254
70N	51	0	0	0	127	152	127	102	51	51	76	76	30	76	127	178	191	178
66N	76	13	0	51	76	102	140	152	254	254	229	140	64	102	89	102	114	127
62N	0	0	0	13	25	25	18	25	23	25	64	64	51	25	51	51	76	127
58N	0	0	0	0	0	0	0	0	0	0	0	5	15	23	25	20	51	127
54N	0	0	0	0	0	0	0	0	0	0	0	0	13	20	13	38	76	114
50N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	13	13	25
46N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	5
42N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66S	91	46	36	23	91	127	137	137	114	800	56	23	23	33	43	53	64	74
70S	323	274	274	274	368	432	483	483	521	508	521	546	635	749	800	813	813	813
74S	559	559	559	635	737	775	826	826	889	966	1092	1092	1092	1051	1651	1651	1651	1651
78S	635	660	737	800	826	889	914	775	559	546	530	559	559	559	625	711	737	867
82S	533	508	476	445	432	406	406	381	381	368	368	368	381	406	406	432	445	445
86S	559	559	559	559	559	559	533	481	457	400	381	343	318	305	332	392	392	305
90S	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	208	183	183

Table A.10b

ACCUMULATION (mm) -- OCTOBER

Table A.10c

ACCUMULATION (mm) -- OCTOBER

Table A.10d

ACCUMULATION (■) -- OCTOBER

Table A.11a

ACCUMULATION (BB) -- NOVEMBER

Table A.11b

ACCUMULATION (mm) -- NOVEMBER

Table A.11c

ACCUMULATION (■) -- NOVEMBER

Table A.11d

ACCUMULATION (BB) -- NOVEMBER

Table A.12a

ACCUMULATION (mm) -- DECEMBER

Table A.12b

ACCUMULATION (in) -- DECEMBER

Table A.12c

ACCUMULATION (mm) -- DECEMBER

Table A.12d

ACCUMULATION (■) -- DECEMBER

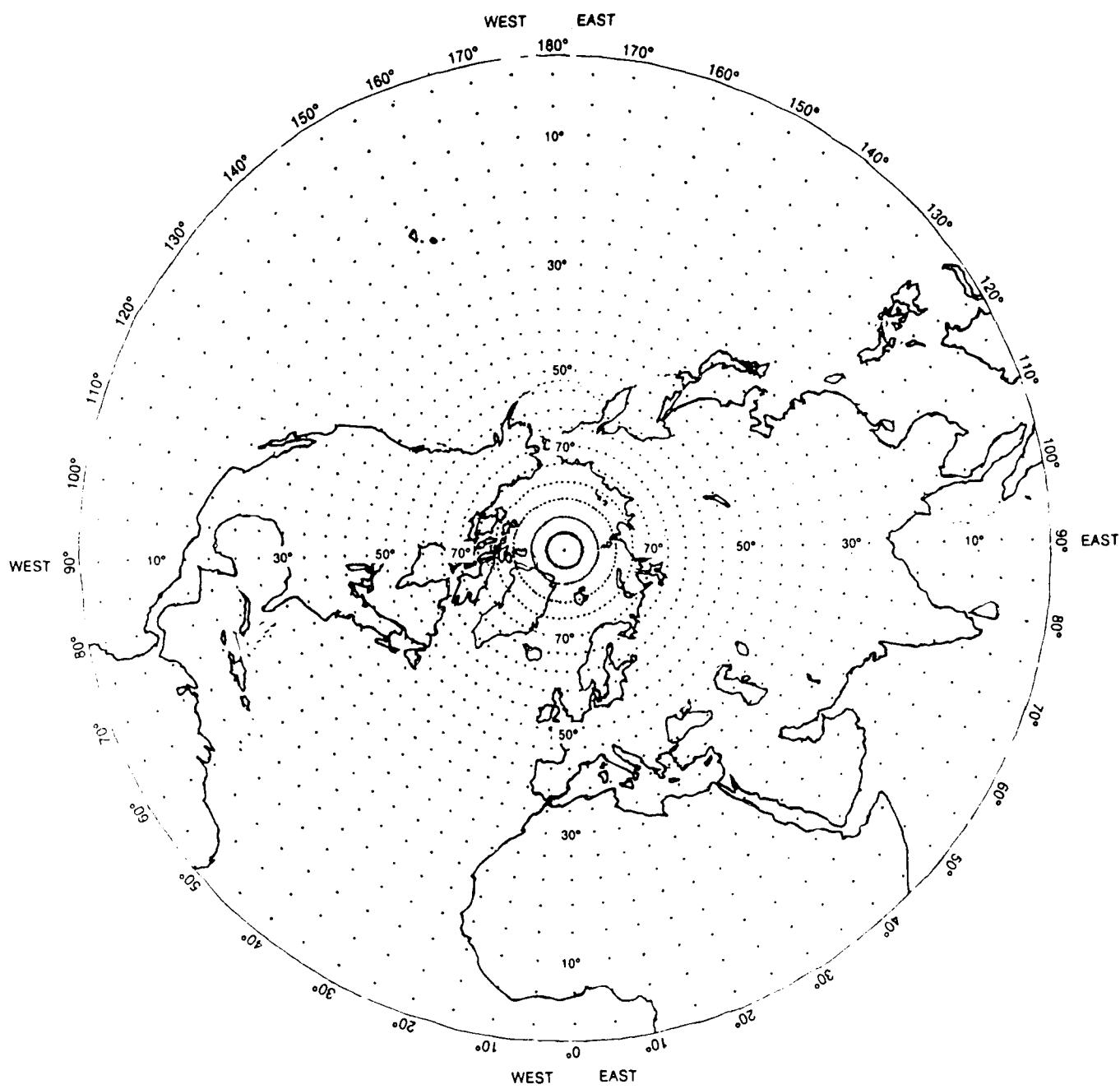


Fig. A.1—Map grid of Northern Hemisphere

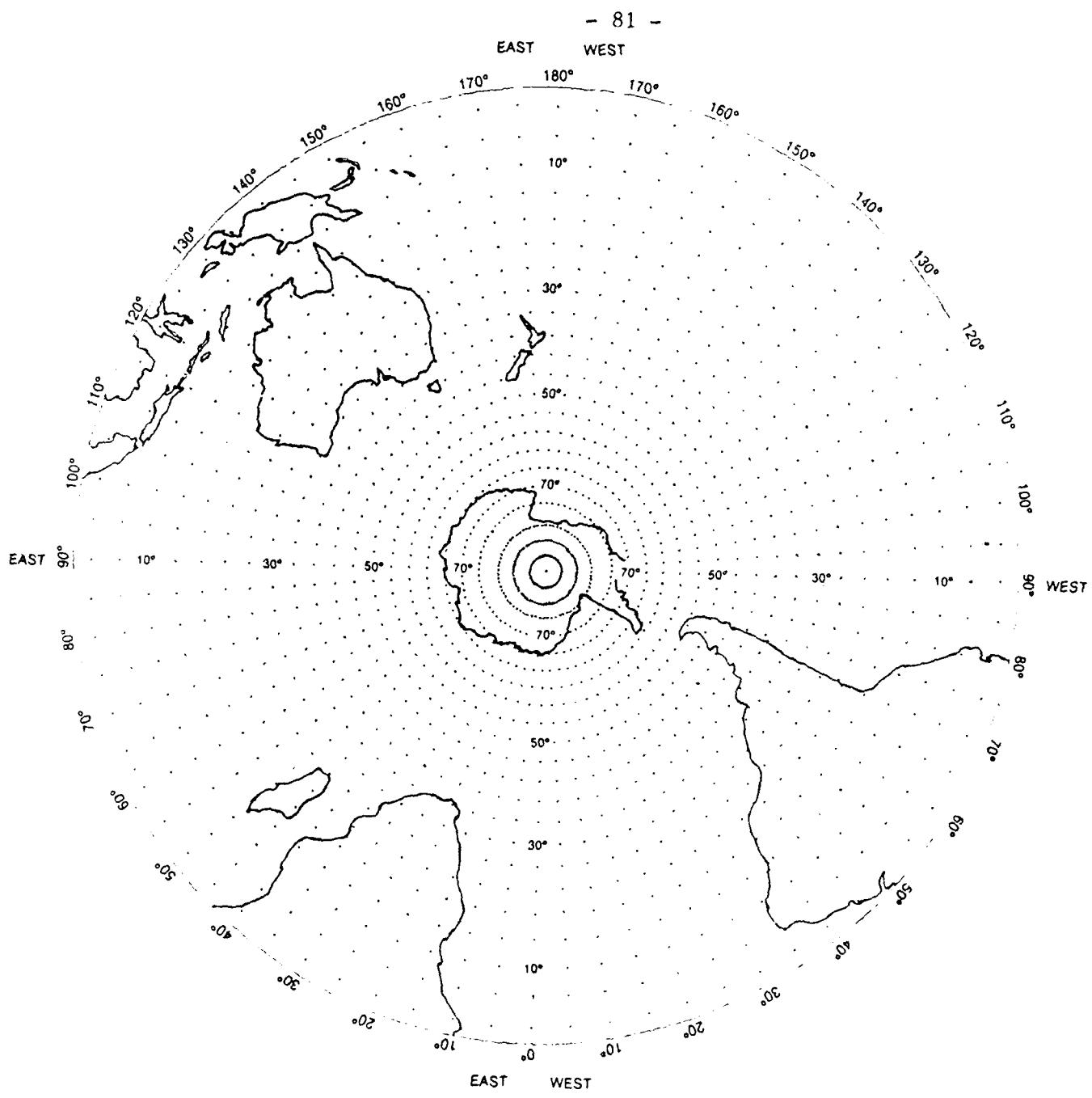


Fig. A.2—Map grid of Southern Hemisphere

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